Taylor Larrechea

Physics 132

Exam 1

Instructions: This exam contains 5 multiple choice questions worth 4 points each and 4 problems worth 20 points each. Do not refer to any book or notes during the exam. The time limit for this test is 50 minutes.

(I)

$+93.5/100$

Section I - Circle the letter that corresponds to the correct answer.

1. A *positive* point charge Q is fixed on a very large horizontal frictionless tabletop. A second *positive* point charge q is released from rest near the stationary charge and is free to move. Which statement best describes the motion of q after it is released?

   a) Its speed will be greatest just after it is released.

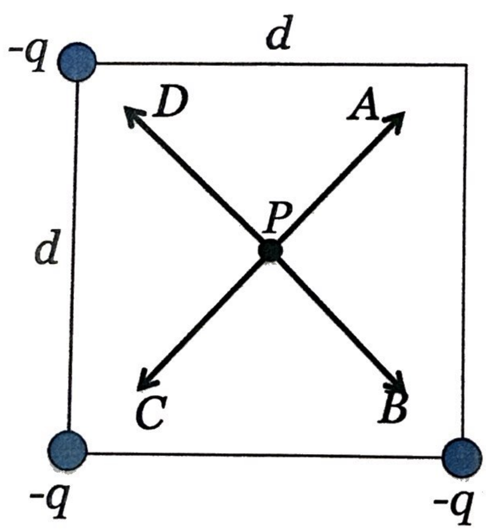
   b) Its acceleration is zero just after it is released.

   c) As it moves farther and farther from Q, its acceleration will keep increasing.

   d) As it moves farther and farther from Q, its speed will decrease.

   e) As it moves farther and farther from Q, its speed will keep increasing.

2. Three equal *negative* points are placed at three of the corners of a square of side d as shown in the figure. Which of the arrows represents the direction of the net electric field at the center of the square at point P?



   a) A

   b) B

   c) C

   d) D

   e) The field is equal to zero at point P.

3. Under electrostatic conditions, the electric field just outside the surface of any charged conductor

   a) is always parallel to the surface.

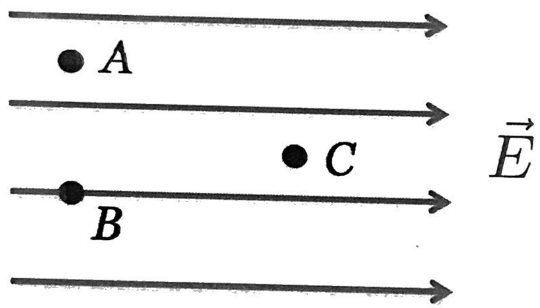
   b) is always zero because the electric field is zero inside conductors.

   c) is always perpendicular to the surface of the conductor.

   d) is perpendicular to the surface of the conductor only if it is a sphere, a cylinder, or a flat sheet.

   e) can have nonzero components perpendicular to and parallel to the surface of the conductor.

4. Suppose a region of space has a uniform electric field, directed towards the right, as shown in the figure. Which statement about the electric potential is true?



   a) The potential at all three locations (A, B, C) is the same because the field is uniform.

   b) The potential at points A and B are equal, and the potential at point C is higher than the potential at point A.

   c) The potential at points A and B are equal, and the potential at point C is lower than the potential at point A.

   d) The potential at point A is the highest, the potential at point B is the second highest, and the potential at point C is the lowest.

5. Two equal positive charges are held in place at a fixed distance. If you put a third positive charge midway between these two charges, the electrical potential energy of the system (relative to infinity) is zero because the electrical forces on the third charge due to the two fixed charges just balance each other.

a) True

b) False

H6/20

Section II - For credit, show all work!

1. Consider the charge configuration in the figure below. (Notice that 1 nC = 1×10^{-9} C)

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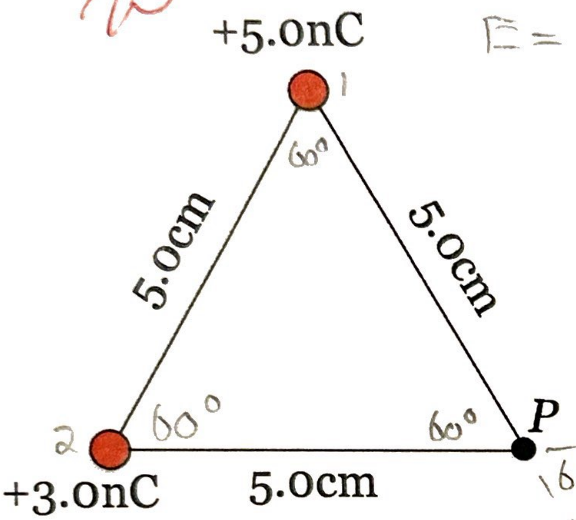
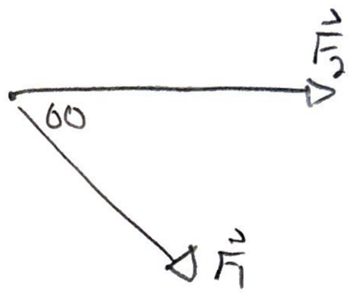
   a) Calculate the net electric field, $\vec{E}$, in unit-vector notation, at the point P.

   b) Find the direction and magnitude of the net electric field at point P.



$E = \frac{KQ}{r^2}$



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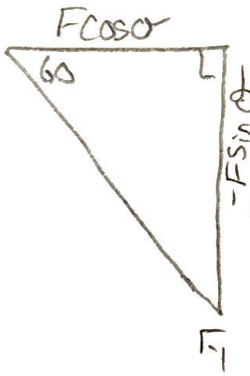
$E_1 = \frac{KQ_1}{(r_1)^2}$ $\quad Q_1 = 5\times10^{-9}C$ $\quad r_1 = 5.0\times10^{-2}m$

$= \frac{9.0\times10^9 \frac{Nm^2}{C^2}(5\times10^{-9}C)}{(5.0\times10^{-2}m)^2}$

$E_1 = 1.8\times10^4 N/C$



$E_2 = \frac{KQ_2}{(r_2)^2}$

$Q_2 = 3.0\times10^{-9}C$

$r_2 = (5.0\times10^{-2}m)$

$E_2 = \frac{9.0\times10^9 \frac{Nm^2}{C^2}(3.0\times10^{-9}C)}{(5.0\times10^{-2}m)^2}$

$E_2 = 10800\, N/C\, \hat{i}$

$E_1 = E_{1x} + E_{1y}$

$E_{1x} = E\cos 60$

$E_{1y} = -E\sin 60$

$E_1 = 9\times10^3 N/C\, \hat{i} - 15588.46\hat{j}$

$E = E_1 + E_2$

$\tan\theta = \frac{y}{x}$

$\theta = \tan^{-1}(\frac{y}{x})$

$\vec{E} = 1.98\times10^4 N/C\, \hat{i} - 1.56\times10^4 N/C\, \hat{j}$

$E = 2.52\times10^4 N/C$

$\theta = 38°$ Clockwise from what?

-1/2

2. A parallel-plate capacitor is formed from two 6.0-cm-diameter electrodes spaced 2.0 mm apart. The plates are charged to ±16 nC. (Notice that 1 nC = 1×10^{-9} C)

a) What is the electric field strength between the disks?

b) A proton is shot from the negative plate toward the positive plate. What launch speed must the proton have to just barely reach the positive disk?

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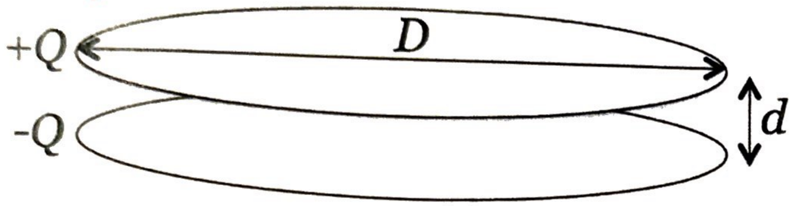

$E_{cap} = \frac{\eta}{\epsilon_0}$

$\eta = Q/A$

$A = \pi r^2$

$= \pi(3.0\times10^{-2}m)^2$

$A = 2.827\times10^{-3} m^2$

$r = 3.0\times10^{-2} m$

$\vec{E} = 6.4\times10^5 N/C$

$E_{cap} = \frac{16\times10^{-9}C}{(2.827\times10^{-3}m^2)\epsilon_0}$

$Q = 16\times10^{-9}C$

$\epsilon_0 = 8.85\times10^{-12} \frac{C^2}{Nm^2}$

$s = 2\times10^{-3}m$

$U = qES$

$= 1.60\times10^{-19}C(6.4\times10^5 N/C)(2\times10^{-3}m)$

$U_0 = 2.048\times10^{-16} J$

$\vec{E} = \frac{16E^{-9}C}{2.509E^{-14}m^2}$

$m_p = 1.67\times10^{-27}kg$

$E = 6.4\times10^5 N/C$

$E_0 = E_1$

$\cancel{U_0} + K_0 = U_1 + \cancel{K_1}$

$\frac{1}{2}m_p v_0^2 = 6.4\times10^5 N/C$

$V_0 = \sqrt{\frac{2U_0}{m_p}}$

$V_0 = 495,247 m/s$

$V_1 = \sqrt{\frac{2(2.048\times10^{-16}J)}{1.67\times10^{-27}kg}}$

$V_1 = 495,247 m/s$

$\approx 4.96\times10^5 m/s$

$\boxed{\vec{E} = 6.4\times10^5 N/C \quad V_0 = 5.0\times10^5 m/s}$

$$U_{13} = \frac{9.0\times10^{9}(3.0\times10^{-9}C)(-5.0\times10^{-9}C)}{(5.0\times10^{-2}m)^2}$$ $$U_{23} = 9.0\times10^{9}\frac{Nm^2}{C^2}\frac{(5.0\times10^{-9})(-5\times10^{-9})}{(5.0\times10^{-2}m)^2}$$

$\boxed{\cancel{U_{13} = -5.4\times10}}$ $\boxed{-1.35\times10^{-7} J}$ $\boxed{\cancel{U_{23} = -9.0\times10^{-5} J}}$ $\boxed{-4.5\times10^{-6} J}$

3. Consider the charge configuration in the figure below. (Notice that 1 nC = 1×10⁻⁹ C)

   a) Calculate the *electric potential energy* of the charge ensemble.

   b) Calculate the net *electric potential* at the point *P*.

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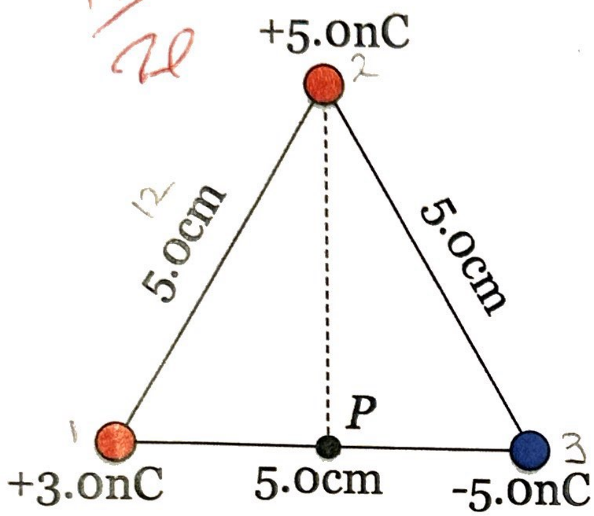
20



$$U = \frac{KQQ}{r^2}$$

$$V = \sum V$$

$$V = \frac{KQ}{R}$$

$$U_{12} = \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(5.0\times10^{-9}C)(3.0\times10^{-9}C)}{(5.0\times10^{-2}m)^2}$$

$\boxed{\cancel{U_{12} = 5.4\times10^{-5} J}}$

$\boxed{1.35\times10^{-7} J}$

$$V_1 = \frac{KQ_2}{r_1}$$

$$= \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(5.0\times10^{-9}C)}{(5.0\times10^{-2}m)^2}$$

$$V_2 = \frac{KQ_3}{r_2}$$

$$= \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(-5.0\times10^{-9}C)}{5.0\times10^{-2}m^2}$$

$V_1 = 900V$

$V_2 = -900V$

$V_3 = 540\ V$

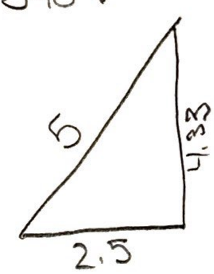
$$V_3 = \frac{KQ_1}{r_3}$$

$$= \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(3.0\times10^{-9}C)}{5.0\times10^{-2}m}$$

$V = V_1 + V_2 + V_3$

$= 900V - 900V + 540V$

$V = 540V$



$c^2 = a^2 + b^2$

$b = 4.33$

At P $\quad V_{1P} + V_{2P} + V_{3P}$

$$V_{1P} = \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(3.0\times10^{-9}C)}{(2.5\times10^{-2}m)}$$

$V_{1P} = 1080V$

$$V_{2P} = \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(+5.0\times10^{-9}C)}{(4.33\times10^{-2}m)}$$

$V_{2P} = 1040\ V$

$$V_{3P} = \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(-5.0\times10^{-9}C)}{(2.5\times10^{-2}m)}$$

$V_{3P} = -1.8\times10^{3}\ V$

$V_{net} = V_{1P} + V_{2P} + V_{3P}$

$\boxed{V_{net} = 320\ V}$

$\boxed{U = -4.5\times10^{-6} J}$

4. Two small metal cubes, *each* with a mass $m = 2.5$ g, are tied together by a 8.4-cm-long massless string and are at rest on a frictionless surface. One metal cube is charged to $q_1 = -2.8\ \mu$C and the second metal cube is charged to $q_2 = -5.6\ \mu$C. (1 μC = 1×10^{-6} C)

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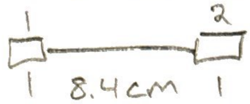
a) What is the tension in the string?

b) Calculate the energy of this system.

c) The string is cut. What is the speed of each cube when they are very far apart?



$m = 2.5g$

$q_1 = -2.8\times10^{-6}C$
$q_2 = -5.6\times10^{-6}C$

$F = \frac{kqq}{r^2} = \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(-2.8\times10^{-6}C)(-5.6\times10^{-6}C)}{(8.4\times10^{-2}m)^2}$ ✓

$\boxed{\vec{F} = 20N}$ ✓

b. $U = \frac{kqq}{r}$ ✓

$U = \frac{9.0\times10^{9}\frac{Nm^2}{C^2}(-2.8\times10^{-6}C)(-5.6\times10^{-6}C)}{(8.4\times10^{-2}m)}$

$\boxed{U_0 = 1.68J}$ ✓

c. $E_0 = E_1$ ✓

$U_0 + \cancel{K_0}^{0} = \cancel{U_1}^{0} + K_1$

$U_0 = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2$ ✓

$U_0 = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B\left(\frac{m_A v_A}{m_B}\right)^2$

$2U_0 = m_A v_A^2$

$\sqrt{\frac{2U_0}{m_A}} = v_A$

$m_A v_A = m_B v_B \quad v_B = v_A$

$v_B = \frac{m_A v_A}{m_B}$

v_a originally $= 0$

$v_B = \frac{2.5\times10^{-3}kg(36.7m/s)}{2.5\times10^{-3}kg}$

$v_B = 36.7m/s$

$\boxed{v_A = 36.7m/s \quad v_B = 36.7m/s}$ ✗

−2